Testing Framework for Characterization of Dynamic Spectrum Access Performance in Policy-Based Radio Networks

Change Log

Version Number	Section	Change
0.1.010311	2.2	Added applicable documents
	6.4	Removed all procedures that were TBD
	8.2	Modified purpose and procedures for clarity
0.1.011111	5	OTA test moved to Section 5
	5.3.13	Added multiple abandonment test
1.0.012511	N/A	Distributed to JTEN DSA/CR WG for comments
1.1.063011	4.3	Added wording to address non-master/slave networks throughout entire document
	4.3	Replaced circuit setup diagrams with editable figures. Added RF switch to figures.
	4.4	Split "initial network formation time" into "initial new" and "final" network formation time
	5.3.7	Added new chracteriation purpose and procedures
	5.3.13	Rewrite purpose based on NRL comments
	5.3	Modify purpose and procedures
	N/A	Remove Foreward as per public release security guidance
	N/A	Incorporate comments from NRL and NTIA
	8	Updated purpose and procedures for clarity
1.2.081611	8	Removed section from version 1.*. Will be included in future version with detailed field testing procedures.

Table of Contents

1. Scope

1.1 Purpose

This document establishes an extensible test plan framework to characterize the Dynamic Spectrum Access (DSA) performance of DSA-enabled policy-based radio (PBR) networks. The framework provides a baseline for characterization and testing of the emerging DSA technology, with extensions to enable ideal lab conditions as well as real field environments. The definitions and components included in the framework allow for clear communication among different parties to ensure that test results can be compared, and performance can be evaluated in a repeatable manner. As such, the framework is structured to be flexible, and encourages participation across the DoD, commercial, and international communities.

DSA PBR network performance characteristics include Abandonment Time, Formation Time, Join Time, and Migration Time. This document does not address hardware radio performance tests. See Section 2.2 for hardware test procedures.

1.2 Background

Dynamic Spectrum Access is emerging as one of the key technologies to enable the Department of Defense (DoD) to meet its increasing requirements for access to the RF spectrum.

Legacy radio systems are not DSA-enabled and are assigned a static set of frequencies they can utilize, while no other systems are permitted on those frequencies. This restrictive allocation approach prohibits non-assigned users from accessing entire blocks of spectrum assigned to the legacy radio, regardless of the utilization factor by the assigned user.

Policy-based radios with DSA functionality allow for improved efficiency of available spectrum utilization. The use of DSA-enabled systems will permit multiple networks and devices to operate in the same slice of spectrum with minimal interference to each other. This is achieved with the use of listen-before-talk policies, RF sensing algorithms, and other techniques. DSA policies are programmable sets of rules that govern the behavior of radios. The policies dictate channels that are allowed or disallowed by the system, depending on given operational or environmental criteria. There are two types of policies: Regulatory Policy (RP) and System Policy (SP). Regulatory Policies are specified by a regulatory authority, such as the NTIA in the United States, and describe what constitutes valid use of spectrum without having specific knowledge of the operational RF environment. The purpose of the RP is to identify critical systems that can tolerate 0% interference, and to prevent other systems from using those portions of the spectrum. System Policies are specified by a system administrator, such as a Signal Officer, and may specify certain entitlements and restrictions on the radio above and beyond those allowed by the RP. The purpose of the SP is to facilitate communications during an active engagement, and specify parameters such as priority of communications, emergency channels, TX power constraints, etc., during that engagement.

A DSA-enabled PBR can use parts of the spectrum that are assigned to other systems while the assigned systems are not using that spectrum. DSA enables the radio network to sense if an assigned user is accessing the spectrum, and if the spectrum is being utilized, the DSA system will find another unoccupied portion of the spectrum to operate in. DSA is also very useful to help radio systems avoid interference. When a DSA-enabled radio senses interference on its operating channel, the radio is aware of the total spectral environment and is able to change its operating frequency to avoid the interference, with minimal disruption to its communications.

DSA represents a promising approach to alleviate the spectrum shortage in the military and civilian environments. However, one of the key issues surrounding continued research and development of DSA systems concerns the need to test and evaluate the performance of DSA in avoiding interference to assigned spectrum users, avoiding interference from assigned users to itself, as well as evaluating the performance of the DSA radio network in the presence of various types of other potential interference. There is an extensive installed base of entrenched legacy systems around the world with which DSA would have to coexist. To enable benign coexistence, a standardized framework must be in place to identify key performance metrics, operational situations and environments of DSA-enabled PBRs. For example, if an assigned user begins to transmit on a frequency being occupied by a DSA PBR, the times required to identify the user, abandon the channel, reform the network, and start communicating on an alternate channel are all important parameters with respect to interference avoidance and radio network performance. The PBRs must be fully characterized to ensure the impact of coexistence and spectrum sharing is understood prior to mass deployment.

1.3 General Applicability

This document is applicable to any DSA-enabled policy-based cognitive radio

1.4 Structure

The document has one primary section: the main body. The main body contains the procedures and setups for the characterization of DSA-enabled policy-based radios.

1.5 Test Designations

The hardware, networking, policy and associated test and measurement procedures in this framework are designated in accordance with an alphanumeric coding system. Each procedure is identified by a two-letter combination followed by a three-digit number. The number is for reference purposes only. The meaning of the individual letters is as follows:

D = DSA
EM = Electromagnetic
HW = Hardware
N = Networking
M = Metric
P = Policy
QS = Quality of Service

SF = Suggested Field Test

a. DSA networking tests are designated by “DN---.”
b. DSA metric measurements are designated by “DM---.”
c. DSA policy tests are designated by “DP---.”
d. Electromagnetic environment setups are designated by “EM---.”
e. General networking measurements are designated by “GN---.”
f. Hardware tests are designated by “HW---.”
g. Suggested field tests are designated by “SF---.”
h. “---“ = numerical order of tests from 101 to 199.

2. Applicable Documents

2.1 General

This section includes the documents cited in other sections of this document or recommended for additional information or as examples.

2.2 Government Publications

DEPARTMENT OF DEFENSE (DoD)

MIL-STD-449	-	DoD Military Standard on Measurement of Radio Frequency Spectrum Characteristics
MIL-STD-461F	-	DoD Interface Standard for Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

2.3 Nov-Government Publications

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE STD 1900.1-2008	-	IEEE Standard Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management

3. Definitions

3.1 General

The following definitions are applicable for the purpose of this test plan.

3.2 Acronyms used in this document

AWG	-	Arbitrary Waveform Generator
BER	-	Bit Error Rate
DSA	-	Dynamic Spectrum Access
DUT	-	Device Under Test
EME	-	Electromagnetic Environment
LOS	-	Line Of Sight
MANET	-	Mobile Ad-Hoc Network
NTA	-	Network Traffic Analyzer
OAT	-	Over-the-Air Time
PBR	-	Policy-Based Radio
PER	-	Packet Error Rate
RF	-	Radio Frequency
RFCS	-	RF Combiner/Splitter
RP	-	Regulatory Policy
RSA	-	Real-time Spectrum Analyzer
SIR	-	Signal Intercept Receiver
SP	-	System Policy
TBD	-	To Be Determined
VA	-	Variable Attenuator

4. FRAMEWORK

4.1 Scope

The testing framework deals with the radio frequency (RF) aspects of DSA, as well as the overall radio network performance of DSA systems.

4.2 Objective

The main purpose of DSA is to deal gracefully with the perturbations in the electromagnetic environment (EME). To address those issues, the test framework focuses on the following types of perturbations:

- Appearance of interferer or assigned user on a frequency currently occupied by the DSA-enabled PBR
- Change in position, time, or other environmental parameters that change the policy currently in force
- Increase in propagation (path) loss between two groups of network nodes
- Convergence of network nodes that have been previously separated due to poor path loss between them

The first two items listed are generic for any DSA PBR. The last two items apply specifically to DSA Mobile Ad-Hoc Networks (MANETs), which are an important subclass of DSA systems. To reproduce these effects in the laboratory, we must force adaption of the DSA radio network in response to a forced change in EME or policy variable. Thus, we need to perform the following:

- Configure the DSA system or network
- Load relevant policies
- Simulate the background EME
- Prepare measuring equipment
- Apply the interference or simulate other EME change, such as position change
- Measure and record the relevant performance metrics

Therefore, a DSA test involves an independent selection of the following elements:

- Configuration and size of the DSA network
- Policy in force during the test
- The simulated EME
- Type of interference, e.g. wideband vs. narrowband
- Network locations affected by the interference
- Any other variables that can affect policy decisions, such as position, altitude, etc.

4.3 Setup

The specific steps for setting up a DSA network are largely dependent on the manufacturer of the system. However, the general approach to the test is independent of the PBR type.

For networks capable of multiple nodes, a four-node network is the minimum network size required for the tests, although development of scalability tests will require a greater number of nodes.

In the test procedures of this framework, a radio network using a master-slave configuration is assumed. The Master Node, which may also be referred to as the Base Station Node or Head Node, is the hub of the network. The Slave Nodes are the spokes of the network. All network traffic is routed through the Master to the intended recipients. When interference is observed, any member of the network can transmit a request for change of channel, however any changes are coordinated by the Master Node only. While the Master-Slave configuration is not required to use the test framework, it is important to identify any privileged or control nodes in advance of the test to differentiate interference impacts to these nodes, in comparison to non- privilege or non-control nodes.

If a Master-Slave configuration is not used, and there is no privileged or control node in the DSA network, "master" refers to the first node in the network that performs an expected operation (ie. First to sense an interferer, first to abandon a channel, first to start transmitting on a new channel, etc.), while "slave" refers to any other node that performs an expected operation after the first node has already done so. During the setup of the test circuit, there is no distinction between master and slave nodes.

In addition to the Device Under Test (DUT), which is the PBR node, the essential components of the test circuit are the following:

1. Signal Recorder: The signal recorder must be able to record the RF signal in real-time across the desired frequency range. It is important to use a device that records the time-domain signal continuously over the required test period, rather than a scanning device that tunes serially across the span. Due to hardware limitations, it may be necessary to limit the recording time duration, recording bandwidth, and other recording parameters, in order to reduce the computational and storage space requirements.
2. EME Simulator: The EME simulator simulates the background electromagnetic environment. Section 4.7 describes the various types of simulated EME that may be of interest. The EME simulator may be an arbitrary signal generator or it may be composed of one or more actual emitters. If previously recorded real-world spectrum usage data is available for playback, this can be used to emulate the EME.
3. Interference Simulator: The interference simulator simulates the interference or appearance of the assigned (incumbent) device. Interference may be injected at various points in the network. The interference signal is part of the EME and has the same properties as the general EME signal described in Sec. 8. The chief difference is that the interference is intended to be the trigger for changes in the state of the PBR, while the rest of EME provides the background environment where the changes occur. In many cases, the same piece of test equipment can perform the EME simulation and the interference simulation.

4. Auxiliary Equipment: The auxiliary equipment provides the network loading and network measurement capabilities. It may include power supplies, computers, signal analyzers, waveform generators, network traffic analyzers, microphones, etc.
5. Coupling Network: The coupling network provides the RF connectivity for the PBR network. A functional coupling network may be achieved in various ways, and it is up to the user to determine the proper networking components. The network may consist of directional couplers, splitters/combiners, RF switches, and many other components. The user must ensure all components of the coupling network meet the frequency requirements of the DSA PBRs under test.

4.3.1 Single DSA PBR Network

Fig. 4.1 illustrates a single N-node DSA PBR network setup. The interference signal may be injected at various points in the network, as represented by the dotted lines. The variable attenuators shown may be used to simulate variable path loss in the PBR network. The RF Switch is used for situations where one PBR node needs to be isolated from the network, prior to allowing it to join. In situations where the RF switch is not required, it will remain closed for the entire characterization.

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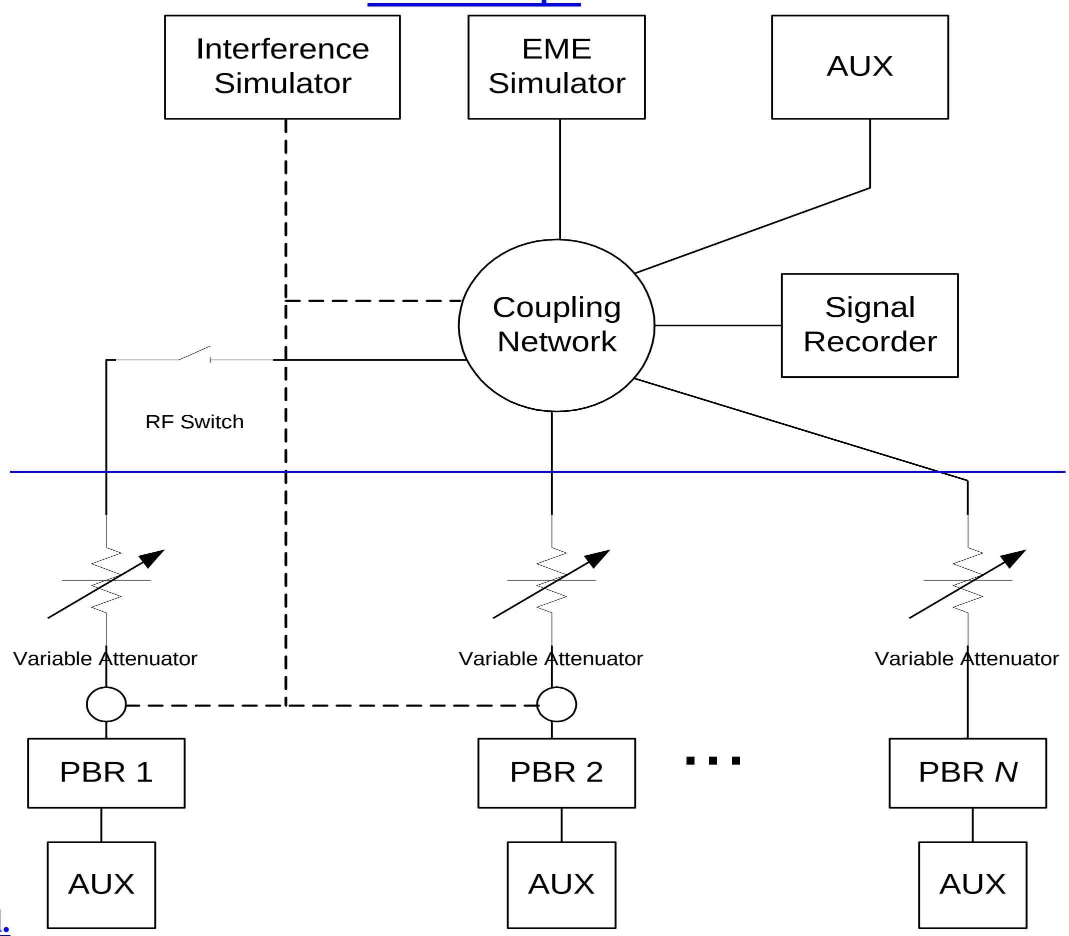

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Figure 4.1: Single DSA PBR Network

4.3.2 Multiple DSA PBR Networks

Fig. 4.2 illustrates the circuit setup for two DSA PBR networks, one with *k* nodes and the other with *N*-*k* nodes. This setup is required in such characterizations as network fragmentation, collision, and coalescence. Adjustable attenuators shown may be used to simulate the variable path loss within a PBR network, as well as the path loss between multiple PBR networks. The RF Switch is used for situations where one PBR network needs to be isolated from the other network, prior to allowing them to coalesce. In situations where the RF switch is not required, it will remain closed for the entire characterization. While not pictured, an interference signal may be injected at various points in the network, similar to Fig. 4.1.

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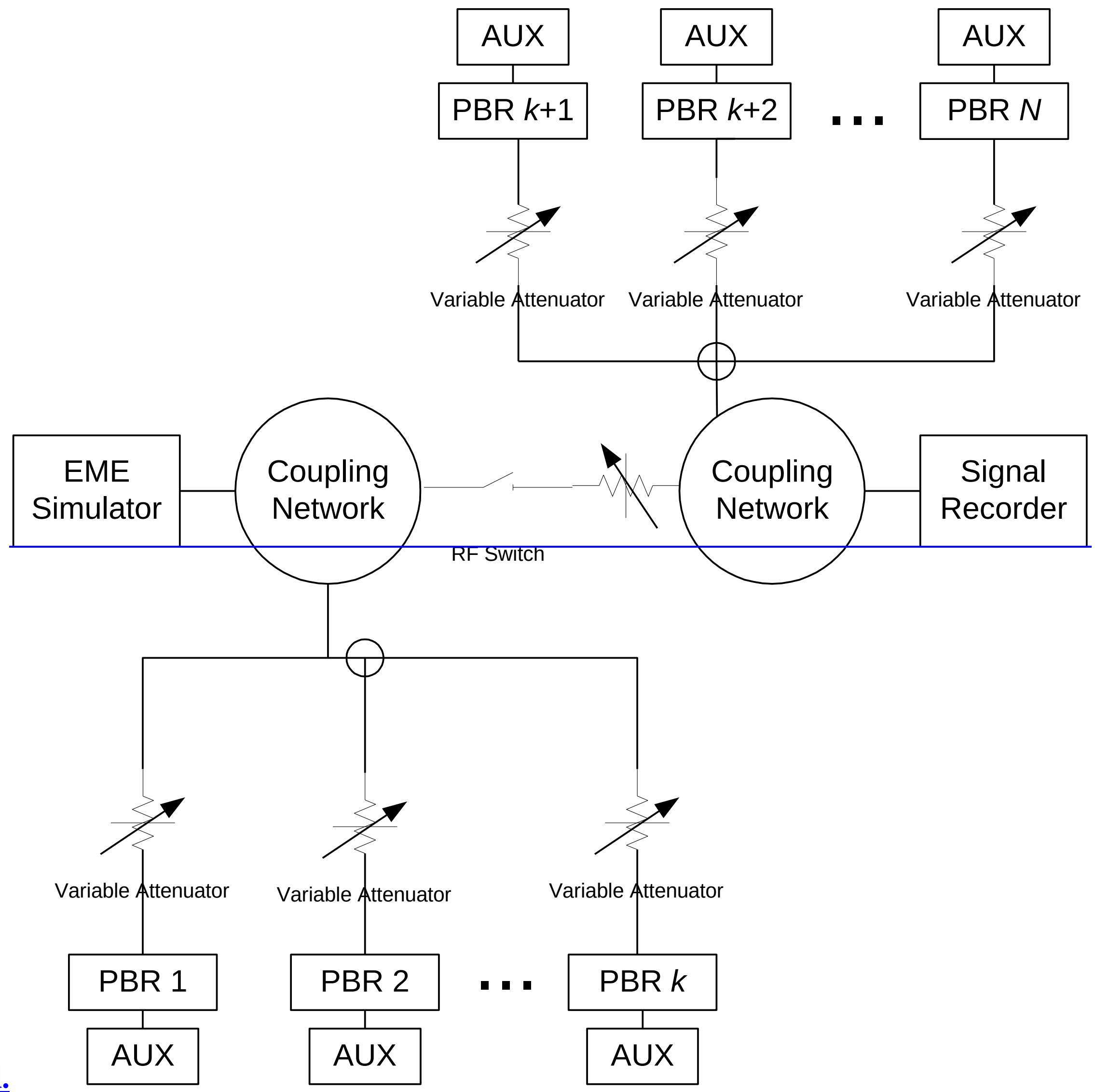

Figure 4.2: Multiple DSA PBR Networks

4.3.3 Coexistence of DSA PBR Network and Legacy Wireless Network Devices

Legacy radio systems may be used to introduce interference to the DSA network. Likewise, DSA PBRs may be used as interference generators to test coexistence with legacy radios. Legacy radios are often referred to as Wireless Network Devices (WNDs). The setup illustrated in Fig. 4.3 allows for testing of spectrum sharing and utilization among various DSA and non-DSA legacy systems. The adjustable attenuators shown may be used to simulate variable path loss in the PBR network.

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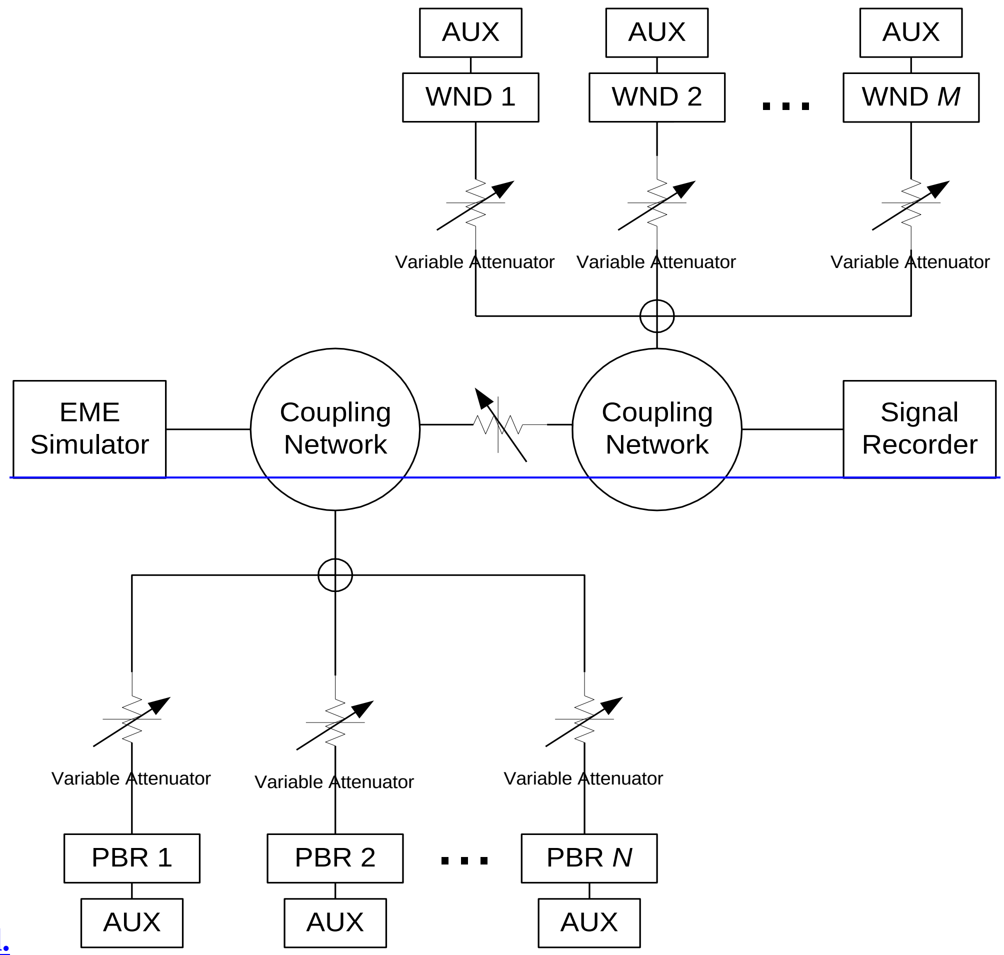

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Figure 4.3: DSA PBR Network and Wireless Network Devices (WND)

4.4 DSA Performance Parameters

The DSA PBR network performance is characterized by DSA-specific metrics. These metrics are enumerated below. Fig. 4.4 illustrates several of the DSA network timing parameters under an interference condition. One or more of these metrics can be characterized within the context of the testing framework. Refer to Section 5.3 for detailed procedures.

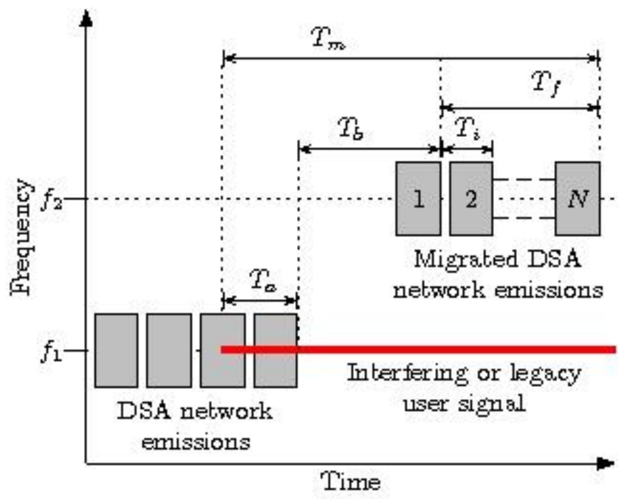

Figure 4.4: Illustration of DSA network timing under interference condition

A. Abandonment Time (T_a): Characterizes the time required for the DSA network to abandon a channel after an assigned spectrum user, or an interference signal, start transmitting on said channel. This is a critical parameter since an assigned user must know the specific amount of interference a system will be receiving to decide whether to enable DSA in that spectrum. While the abandonment time is a system specification that is guaranteed by design, this performance parameter must be tested independently from the manufacturer.
B. Base Network Migration Time (T_b): Characterizes the time it takes for the PBR master node to find an unoccupied frequency, and start transmitting on a newly selected operating frequency, after abandoning the previous channel. If no master node exists, observe the first node to migrate to a new channel.
C. Initial Network Reconnect Time (T_i): Characterizes the time required for the first slave node to reconnect to the master node after a base network migration. If no master or slave nodes exist, observe the time elapsed for second node to start communicating with the first node on the new channel.
D. Final Network Reconnect Time (T_f): Characterizes the required time for the last slave node to reconnect to the master node after a base network migration. If no master or slave nodes exist, observe the time elapsed for last node to join the network on the new channel.
E. Full Network Migration Time (T_m): Characterizes the time it takes for the DSA PBR network to abandon a channel, and have the master node and all connected slave nodes (if no master/slave, observe all nodes) form a network and start communicating on a new channel. This is the sum of abandonment time, base network migration time, and final network reconnect time ($T_m = T_a + T_b + T_f$). The purpose of subdividing the full network migration time into constituent time components is to obtain a better understanding of the scaling of the full migration time as a function of the number of nodes, EME, etc.

F. Initial Network Formation Time: Characterizes the time it takes the first DSA-enabled PBR to connect to the master node, form a network, and start transmitting data across the network. If no master node exists, observe the first two nodes to start communicating with each other on a selected channel. This parameter is to measure the initial formation of a new DSA network defined by the first two nodes to start communicating with each other, after a fresh radio power up, without any channel abandonment or network migration. The formation time may vary according to the DSA PBR network size, operating frequency range, and RF network type (e.g. WiFi, WiMax, etc.). The formation time may also vary if there are pre-assigned frequencies for initial rendezvous. The minimum network size for this test is four nodes.

G. Final Network Formation Time: Characterizes the time it takes the last DSA-enabled PBR to connect to the master node, join the already formed network, and start transmitting data across the network. If no master node exists, observe the last node to start communicating with any other node on a selected channel. This parameter is to measure the completion of the formation of a new DSA network, after a fresh radio power up, without any channel abandonment or network migration. The formation time may vary according to the DSA PBR network size, operating frequency range, and RF network type (e.g. WiFi, WiMax, etc.). The formation time may also vary if there are pre-assigned frequencies for initial rendezvous. The minimum network size for this test is four nodes.

H. Network Join Time: Characterizes the time for one slave node to join a previously formed DSA network of two or more nodes. The time will vary depending on the parameters of the test (e.g. noise, interference, link attenuation, size of network, etc.). The slave node shall not have prior information regarding the network's geolocation, cell size, or operating frequency.

I. Network Fragmentation Time: Characterizes the time for one formed DSA network to fragment and form two smaller DSA networks. This is an important parameter as it predicts performance of DSA network in field situations. Allows for characterization of performance of the DSA network to validate the requirement of continuous, uninterrupted communications among users.

J. Network Collision: Characterizes the performance of the DSA network when two separate co-located DSA networks operate on one frequency. Even though the use of DSA should prevent the two networks from colliding on the same frequency for an extended period of time, it is important to characterize the DSA network behavior to ensure uninterrupted communications among users.

K. Network Coalescence: Characterizes the time required for two separate DSA networks approaching on the same frequency to coalesce into one single network. Even though adjacent networks generally should not coalesce on DSA-enabled PBR networks, network coalescence may be desired in certain tactical situations. It is especially important to characterize the DSA network behavior to ensure uninterrupted communications among users during unusual or unintended scenarios.

L. Network Roaming: Characterizes the ability of a slave node to roam among several DSA networks. This test is important to characterize the DSA network behavior in a mobile environment.
M. Multiple Channel Abandonment Test: Characterizes the ability of the DSA PBR network to correlate channel abandonment requests from two or more nodes. When two or more nodes sense the same interference event, they may independently generate requests for channel abandonment and network migration. A DSA algorithm must be able to correlate multiple abandonment requests to prevent multiple network migrations as result of a single interference event.

4.5 Independent Selection of DSA PBR Network Size

The suggested minimum PBR network size is 4 nodes for a single network setup. User can select any number of nodes in a test network to characterize the effects on performance due to network size variations. Note that the DSA network may show decreased performance with an increase network size.

4.6 Independent Selection of Enforced DSA Policy

PBRs require policies to enable use of DSA on communication networks. Policies dictate channels and/or behaviors that are allowed or disallowed by the system, depending on certain operational and environmental criteria. The suggested policies enumerated below are examples of System and Regulatory Policies, and characterize the functionality and performance of the DSA PBR network. One or more of these policies can be loaded on a PBR to observe the effects on the DSA performance of the radio network. Refer to Section 5.4 for detailed procedures to select and implement the enforced DSA policies.

A. Dynamic Detector Threshold: The detector threshold specifies the levels, in dBm, at which the PBR can identify an assigned user or an interference signal causing the DSA network to abandon an operating channel. It is important to verify the capability of the PBR to dynamically adjust the detector threshold if it is too sensitive or not sensitive enough, depending on the operating RF environment of the DSA network. This characteristic is unique to systems employing energy sensing algorithms. Note the Dynamic Detector Threshold is a test of the capability of the DSA PBR only, not a test of a mode of operation. If dynamic thresholds are employed, a related system policy must also be in place to adjust transmitter parameters to ensure coexistence.
B. Power Control: Transmitter power is an important characteristic that determines if network communication will be successful. This test is used to characterize the effectiveness of a policy to dynamically control transmitter power levels of the PBR.
C. Selective Frequency Map: A frequency map specifies the operating range of the PBR, as well as specific frequency channels that are prohibited for use by DSA networks (as may be specified by a channel plan or other spectrum use regulations.) This test characterizes the effectiveness of a policy to specify frequency bands on which the DSA network may and may not transmit.

D. Geospatial Operation: Geospatial operation requires the DSA network to be aware of its geospatial positioning. This awareness may be achieved through built-in or commercially available GPS simulators, which also allow for the simulation of moving or varying locations. Regulatory and system policies may be created which define geospatial operation within a certain distance of points, lines, or contours. This test characterizes the effectiveness of a policy to control the operation of the DSA network based on geospatial awareness.
E. Time-Based Performance: There are instances in which spectrum restrictions exist during certain days of the month, or certain times of the day. This test characterizes the effectiveness of a policy to control the operation of the DSA network based on parameters of time.
F. Dense/Noisy Environment Performance: With an increased amount of legacy systems being fielded, a decreased amount of spectrum available, and active military engagements all over the world, intentional and unintentional jamming is a major concern. This test characterizes the effectiveness of a policy to maintain communication while sustaining heavy interference or high-power jamming.
G. Threshold Sensing Accuracy: As described for the Dynamic Detector Threshold, the threshold is a vital parameter which enables efficient use of DSA on the PBRs. This test characterizes the sensing accuracy of the detector to ensure the PBR is sensing the proper signal levels which are expected.
H. Composite Policy Performance: In a real field environment, a combination of any of the aforementioned policies may be running on the PBR at the same time. To ensure uninterrupted communications and operation of the PBRs as expected, this test characterizes the performance of the DSA network with multiple policies loaded and running simultaneously.
I. Cooperative Sensing: Characterizes the ability of multiple DSA-enabled PBRs to cooperatively detect and communicate the presence of a hidden node. This is an important characteristic to solve the hidden node problem in multi-node networks.

4.7 Independent Selection of EME

Radio frequencies are never used in an environment devoid of other electromagnetic activity. To simulate real-world conditions of RF environments and characterize their effect on the radio systems, electromagnetic signals need to be introduced with predefined characteristics. These include adjacent channel narrowband, wideband, wideband noise, frequency sweep, frequency hop, and high power signals. This portion of the framework allows for realistic testing in a lab environment, and allows for the creation of a baseline performance metric for a DSA-enabled PBR network. Comparison of baseline results with the EME-stressed results will provide a good indication of the performance of DSA in the field.

EME conditions are crucial to operation of DSA PBR networks. Simulation of an electromagnetic environment for a testbed shall be as realistic as possible to accurately measure the success of the DSA technology. Realistic electromagnetic environments may be achieved by survey, modeling and simulation of a real-world environment in the band of interest. Without such a process, real-world electromagnetic characteristics, including natural and man-made elements, may not be reproduced for testing against a realistic environment. The simulated realistic environment could serve as the electromagnetic ambient and other EME effects could be added to create different testing conditions.

Refer to Section 8 for detailed procedures to simulate EME. The user can introduce one or more of the signals into the DSA radio network.

A. Adjacent Channel Narrowband Signal: Characterizes the performance of the DSA network in the presence of an adjacent channel narrowband signal. The definition of narrowband depends on the frequency band of interest. For example, a common definition of narrowband signal in UHF/VHF range is an occupied bandwidth of ≤ 25 kHz. This signal must be adjacent to the channel on which the DSA network is operating. By decreasing the receiver sensitivity, the narrowband signal can be centered closer to the DSA operating frequency.
B. Wideband Signal: Characterizes the performance of the DSA network in the presence of a wideband signal in the adjacent channel. A wideband signal is defined as a signal having similar power and spectral density as the DSA radio signal.
C. Wideband Noise-Like Signal: Characterizes the performance of the DSA network in the presence of a wideband noise-like signal. A wideband noise signal is defined as a signal with bandwidth greater than twenty times the occupied bandwidth of the DSA signal.
D. Frequency Swept Signal: Characterizes the performance of the DSA network in the presence of a swept signal. A swept signal is a signal generated to sweep the operating band of the PBR. This may also effect the general networking measurements.
E. Frequency Hopping Signal: Characterizes the performance of the DSA network in the presence of a frequency hopping signal. A frequency hopping signal is generated to transmit in the operating frequency band of the PBR. The frequency hop rate should be set to characterize the radio in different simulated EM environments. This may also be performed in conjunction with the wideband or narrowband signals.
F. High Power Signal: Characterizes the performance of the DSA network in the presence of a high power signal. A high power signal is defined as a signal whose power is a pre-determined amount higher relative to the DSA-enabled PBR signal.

4.8 Independent Selection of Other Variables

Other variables may include geolocation, altitude, transmitter power, mobile adhoc networks, various types of legacy systems, and many more. All of these may be introduced into the DSA environment with the use of the framework.

5. DSA Performance Characterization

5.1 Scope

These test procedures describe the method used to characterize DSA performance of networks of DSA-enabled policy based radio in a lab environment. DSA PBR network tests can be performed in conjunction with QoS Measurements, DSA Network Metrics, and EME Setup.

5.2 DSA PBR Network Basic Setup

General guidelines for setting up a DSA network for lab testing are described in Section 4.3, and shall be as follows:

a. Power on all PBRs
b. Ensure RF connections are attenuated for lab safety
c. Check the network configuration of radios to ensure all nodes can communicate with each other
d. Check the test equipment to ensure it is properly connected and operational

5.3 DSA PBR Network Performance Characterization Test Procedures

5.3.1 DN101 Abandonment Time

5.3.1.1 Purpose

The Abandonment Time test procedure is used to characterize the time it takes the DSA network to abandon a channel after an assigned spectrum user, or an interference signal, starts transmitting on said channel.

5.3.1.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)
e. Signal Intercept Receiver (SIR)

5.3.1.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect RSA, AWG, SIR, and PBR master node to coupling network using an attenuator
b. Connect all desired DSA slave nodes to coupling network using attenuators
Establish DSA network and ensure communication between all nodes

5.3.1.4 Procedures

The test procedure shall be as follows:

a. Set the AWG to generate a signal (S_1) co-channel to the PBR nodes, but do not inject the signal to the PBR network

b. Set the SIR to scan the frequency range contained in the Frequency Map of the PBR. Set the time resolution of the SIR to TBD. Verify that the SIR has detected the DSA network signal
c. Inject the signal (S_1) from the AWG to the coupling network and observe that the PBR abandons the current channel
d. Read the time log of the SIR to see how much time elapsed between the detection of S_1 and the last node in the DSA network abandoning the channel

5.3.2 DN102 Base Network Migration Time

5.3.2.1 Purpose

The Base Network Migration Time test procedure is used to characterize the time it takes for the PBR master node ONLY (if no master node exists, observe any first node) to find an unoccupied frequency after abandoning the prior operating frequency, and start transmitting on a newly selected channel. This time does not include the subsequent connection between the master node and the first slave node to migrate. The test must be performed only after the procedure for DN101 is completed, as in Section 5.3.1.

5.3.2.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)
e. Network Traffic Analyzer (NTA)

5.3.2.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect NTA to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect RSA to coupling network
d. Connect all desired PBR slave nodes to coupling network using attenuators
e. Establish DSA network and ensure communication between all nodes

5.3.2.4 Procedures

The test procedure shall be as follows:

a. Record the frequency at which the network is operating
b. Using the AWG, introduce a narrowband signal with the same spectral density at the DSA network operating frequency
c. Monitor the RSA to ensure the DSA network has migrated to a new frequency
d. Monitor the network traffic using the NTA time-stamped traffic log
e. Record the time of the last transmission by the master node made on the original operating frequency (t_1)

f. Record the time of the first transmission by the master node on the new operating frequency (t_2)
g. Calculate Network Migration Time by subtracting t_1 from t_2

5.3.3 DN103 Initial Network Reconnect Time

5.3.3.1 Purpose

The Initial Network Reconnect Time test procedure is used to characterize the time it takes for the first slave node to reconnect to the master node after a base network migration. If no master/slave nodes exist, this procedure characterizes the time it takes for the first two nodes to connect together, form a network, and start transmitting to each other, after a network migration. This test is performed only after DN102 is completed, as in Section 5.3.2. This characterizes the time between when the master node starts transmitting on a new open frequency and when the first slave node in the network switches to that same new frequency and starts communicating with the master node.

5.3.3.2 Test Equipment

The test equipment shall be as follows:

a. See Section 5.3.2.2

5.3.3.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. See Section 5.3.2.3

5.3.3.4 Procedures

The test procedure shall be as follows:

a. Follow all procedures as in Section 5.3.2.4
b. Monitor the network traffic using the NTA time-stamped traffic log
c. Record the time of the first transmission between the first slave node to connect to the network and the master node

5.3.4 DN104 Final Network Reconnect Time

5.3.4.1 Purpose

This test procedure is used to characterize the time it takes for the last slave node in the network to reconnect to the master node after a base network migration. If no master/slave nodes exist, this procedure characterizes the time it takes for the last node to connect to the previously formed network, and start transmitting, after a network migration. This test is performed only after DN102 and DN103 are completed, as in Section 5.3.2 and 5.3.3 respectively. This characterizes the time between when the master node (the first node, if no master node exists) starts transmitting on a new open frequency and when the last slave node (the last node, if no slave node exists) in the network switches to that same new frequency and starts communicating with the master node. The time will vary with the total number of nodes in the network.

5.3.4.2 Test Equipment

The test equipment shall be as follows:

a. See Section 5.3.3.2

5.3.4.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. See Section 5.3.3.3

5.3.4.4 Procedures

The test procedure shall be as follows:

a. Follow all procedures as in Section 5.3.3.4
b. Monitor the network traffic using the NTA time-stamped traffic log
c. Record the time of the first transmission between the last slave node (last node, if no slave exists) to connect to the network and the master node (first node, if no master exists)

5.3.5 DN105 Full Network Migration Time

5.3.5.1 Purpose

This test procedure is used to characterize the time it takes for the full DSA PBR network to abandon a channel, find a new channel, and all nodes to start communicating on new channel. Full network migration time is the sum of abandonment time, base networking migration time, and final network reconnect time. This test is performed only after DN101, DN102, and DN104 are completed, as in Section 5.3.1, 5.3.2, and 5.3.4 respectively. The time will vary with the total number of nodes in the network.

5.3.5.2 Test Equipment

The test equipment shall be as follows:

a. See Section 5.3.4.2

5.3.5.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. See Section 5.3.4.3

5.3.5.4 Procedures

The test procedure shall be as follows:

a. Follow all procedures as in Section 5.3.4.4
b. Monitor the network traffic using the NTA time-stamped traffic log
c. Record the time of the first transmission between the last slave node to connect to the network and the master node

5.3.6 DN106 Initial Network Formation Time

5.3.6.1 Purpose

This test procedure is used to characterize the time it takes the first DSA-enabled PBR to connect to the master node, form a network, and start transmitting data across the network. If no master node exists, observe the first two nodes to start communicating with each other on a selected channel. The metric characterizes the time for initial formation of a new DSA radio network, after a fresh radio power up, without channel abandonment or network migration occurring. It is assumed all radios are fully powered up and operation. The formation time may vary according to the DSA PBR network size, operating frequency range, and RF network type (e.g. WiFi, WiMax, etc.). The formation time may also vary if there are pre-assigned frequencies for initial rendezvous. It is assumed there are no pre-assigned frequencies for network startup. The user must note if a pre-assigned frequency exists, and record the frequency. The minimum network size for this test is 4 nodes.

5.3.6.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Real-time Spectrum Analyzer (RSA)
d. Variable Attenuators (VA)
e. Network Traffic Analyzer (NTA)
f. RF Switch

5.3.6.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect NTA to coupling network
b. Connect PBR Node 1 (master node if master/slave architecture is used) to RF Switch using an attenuator
c. Connect RF Switch to coupling network
d. Connect RSA to coupling network
e. Connect all desired PBR nodes (or slave nodes if master/slave architecture is used) to coupling network using attenuators
f. Establish DSA network and ensure communication between all nodes

5.3.6.4 Procedures

The test procedure shall be as follows:

a. Power up all radios
b. RF switch s1 is set to open position. The traffic analyzer should show no subscriber activity on the master node
c. Close s1 to connect all node to the Node 1. Monitor the traffic analyzer for subscriber network entry activity

d. Follow message sequence with time stamps to determine network formation and commencement of communication
e. Monitor spectrum usage to ensure network formation on the RSA
f. Record the initial network formation time
g. Record the RF network type, DSA PBR network size, operating frequency range, whether the initial rendezvous frequency is pre-assigned, and any other relevant information

5.3.7 DN107 Final Network Formation Time

5.3.7.1 Purpose

This test procedure is used to characterize the time it takes the last DSA-enabled PBR to connect to the master node, join the previously formed network, and start transmitting data across the network. If no master node exists, observe the last node to start communicating with any other node on a selected channel. The metric characterizes the time for final formation of a new DSA radio network, after a fresh radio power up, without channel abandonment or network migration occurring. It is assumed all radios are fully powered up and operational. This test characterization must be performed in conjunction with Initial Network Formation Time (Section 5.3.6).

5.3.7.2 Test Equipment

The test equipment shall be as follows:

a. See Section 5.3.6.2

5.3.7.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. See Section 5.3.6.3

5.3.7.4 Procedures

The test procedure shall be as follows:

a. See Section 5.3.6.4

5.3.8 DN108 Network Join Time

5.3.8.1 Purpose

This test procedure is used to characterize the time for one node to join a previously formed DSA network of two or more nodes. The time will vary depending on the parameters of the test (e.g. noise, interference, link attenuation, network size, operating frequency range, channel bandwidth, etc.). The joining node should not have prior information regarding the network's geolocation, network size, or operating frequency.

5.3.8.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)

c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)
e. Network Traffic Analyzer (NTA)
f. RF Switch

5.3.8.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect NTA to coupling network
b. Connect RSA to coupling network
c. Connect all desired PBR nodes to coupling network using attenuators
d. Connect one PBR node to coupling network using the RF Switch
e. Establish DSA network and ensure communication between all nodes on each network

5.3.8.4 Procedures

The test procedure shall be as follows:

a. RF switch s1 is set to open position. The traffic analyzer should show no subscriber activity on PBR Node 1 disconnected by the open switch
b. Monitor the NTA and RSA to make sure all nodes are operating and network is fully formed
c. Close s1 to connect the slave node to the DSA network
d. Record the time stamp at which the switch was closed (t1)
e. Record the time when the PBR Node 1 starts to transmit data on the DSA network (t2)
f. Calculate Network Join Time by subtracting t1 from t2. For precise measurement, account for the delay through the RF switch.

5.3.9 DN109 Network Fragmentation Time

5.3.9.1 Purpose

This test procedure is used to characterize the time it takes one formed DSA network to fragment and form two smaller DSA networks. Observe performance of network to ensure the two networks do not interfere with each other in any way. The minimum size for this test is 8 nodes.

5.3.9.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Real-time Spectrum Analyzer (RSA)
d. Network Traffic Analyzer (NTA)

5.3.9.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect NTA to coupling network

b. Connect PBR Node 1 (master node, if master/slave architecture is used) to coupling network using an attenuator
c. Connect RSA to coupling network
d. Connect all desired PBR nodes (slave nodes, if master/slave architecture is used) to coupling network using attenuators
e. Establish DSA network and ensure communication between all nodes

5.3.9.4 Procedures

The test procedure shall be as follows:

a. Force network fragmentation
b. Monitor NTA to determine the time it takes for one large network to fragment into two smaller networks, and for the two smaller networks to become operational and transmit data on their respective networks

5.3.10 DN110 Network Collision

5.3.10.1 Purpose

This test procedure is used to characterize the performance of the DSA network when two separate co-located DSA networks operate on one frequency in the same geographical area. While this should not happen when using dynamic spectrum access, this characterization is important to see how the PBR would deal with such an event. The minimum size for this test is two DSA networks consisting of 4 nodes each, for a total of 8 nodes.

5.3.10.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Real-time Spectrum Analyzer (RSA)

5.3.10.3 Setup

The test setup is described and shown in Section 4.3.2, and shall be as follows:

a. In two setups of the DSA network, connect PBR Node 1 (master node, if master/slave architecture is used) to coupling network using an attenuator
b. In two setups of the DSA network, connect RSA to coupling network
c. In two setups of the DSA network, connect all desired PBR nodes (slave nodes, if master/slave architecture is used) to coupling network using attenuators
d. In two setups, establish DSA networks and ensure communication between all nodes

5.3.10.4 Procedures

The test procedure shall be as follows:

a. Check formation of two separate DSA networks using RSA.
b. Lock in both networks to operate on the same single frequency channel.

c. Perform general network measurements to characterize the performance of the network, as described in Section 5.3

5.3.11 DN111 Network Coalescence Time

5.3.11.1 Purpose

This test procedure is used to characterize the time it takes two separate DSA networks approaching on the same frequency to coalesce into one single network. While this should generally not happen when using dynamic spectrum access, this may be desired in certain tactical situations. This characterization is important to see how the DSA network would deal with such an event. The minimum size for this network test is 8 nodes.

5.3.11.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.3.11.3 Setup

The test setup is described and shown in Section 4.3.2, and shall be as follows:

a. In two setups of the DSA network, connect PBR master node to coupling network using an attenuator
b. In two setups of the DSA network, connect RSA to coupling network
c. In two setups of the DSA network, connect all desired PBR slave nodes to coupling network using attenuators
d. In two setups, establish DSA networks and ensure communication between all nodes

5.3.11.4 Procedures

The test procedure shall be as follows:

a. Form two DSA networks operating on different frequencies
b. Monitor NTA and RSA to ensure operation of two separate networks
c. Force network coalescence
d. Record time (t1) at the last data transmission from the two separate DSA networks
e. Record time (t2) when the last slave node connects to the master node and starts transmitting on the coalesced DSA network
f. Perform general QoS measurements as described in Section 6 to monitor performance of DSA network during coalescence.
g. Calculate network coalescence time by subtracting t1 from t2

5.3.12 DN112 Network Roaming Time

5.3.12.1 Purpose

This test procedure is used to characterize the ability of a node to roam among several different DSA networks. This characterization is important to see how the DSA network would deal with such an event.

5.3.12.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.3.12.3 Setup

The test setup is described and shown in Section 4.3.2, and shall be as follows:

a. In two setups of the DSA network, connect PBR master node to coupling network using an attenuator
b. In two setups of the DSA network, connect RSA to coupling network
c. In two setups of the DSA network, connect all desired PBR slave nodes to coupling network using attenuators
d. In two setups, establish DSA networks and ensure communication between all nodes on each network

5.3.12.4 Procedures

The test procedure shall be as follows:

a. Form two DSA networks operating on different frequencies
b. Monitor NTA and RSA to ensure operation of two separate networks
c. Gradually increase attenuation between slave node and Master 1 while decreasing attenuation between slave node and Master 2 to simulate the slave node moving farther away from Master 1 and moving closer to Master 2
    a. If master/slave configuration is not used, refer to Master 1 as PBR Node 1, Master 2 as PBR Node k+1, and slave node as PBR Node 2.
d. Record time (t1) at the last data transmission from the slave node to Master 1
e. Record time (t2) at the first data transmission from the slave node to Master 2
f. Perform general QoS measurements as described in Section 6 to monitor performance of DSA network during roaming
g. Calculate network roaming time by subtracting t1 from t2

5.3.13 DN113 Multiple Channel Abandonment Test

5.3.13.1 Purpose

This test procedure characterizes the ability of the DSA PBR network to correlate channel abandonment requests from two or more nodes. When two or more nodes sense the same interference event, they may independently generate requests for channel abandonment and network migration. A DSA algorithm must be able to correlate multiple abandonment requests to prevent multiple network migrations as result of a single interference event. The DSA network must coordinate any channel abandonment so only one network migration occurs as a result of any one interference event. If a DSA algorithm is unable to correlate interference reports generated by the nodes to the sensing events observed by those nodes, a single interference event may result in multiple channel abandonments and migrations. This will result in degraded QoS, and overall loss of performance of the DSA PBR network.

5.3.13.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.3.13.3 Setup

The test setup is described and shown in Section 4.3.1, and shall be as follows:

a. Connect RSA and AWG to the coupling network
b. Connect all desired DSA PBR nodes to the coupling network
c. Establish DSA network and ensure communication between all nodes

5.3.13.4 Procedures

The test procedure shall be as follows:

a. Using the RSA, record the settled frequency of the DSA network
b. Using an Interference Simulator, introduce an interference signal at the recorded DSA frequency
c. Observe the performance of the DSA network. Channel abandonment and network migration should occur only once

5.3.14 DN114 Over-the-Air Time

5.3.14.1 Purpose

This test procedure is used to characterize the amount of time the radio is transmitting data into the RF spectrum.

5.3.14.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.3.14.3 Setup

This section is reserved for the description of the setup for this characterization

5.3.14.4 Procedures

This section is reserved for the description of the procedures for this characterization

5.4 Policy-Based Control Test Procedures

5.4.1 DP101 Dynamic Detector Threshold

5.4.1.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to control the detector threshold of a PBR. The policy generates a sensitivity curve based on an estimate of signal density in the environment. The sensing accuracy applies to the threshold level which the radio is able to sense if there is another signal on the same frequency. This may be used in case of policy where operating in area with low signal power, thus need higher accuracy to detect signals.

5.4.1.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.1.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
d. Establish DSA network and ensure communication between all nodes

5.4.1.4 Procedures

The test procedure shall be as follows:

a. Create Sensing Accuracy policy (e.g. If all you see is noise, lower the threshold level incrementally until the network is seen.)
b. Load Sensing Accuracy policy onto all PBR nodes
c. Introduce the appropriate AWG signal to test the sensing accuracy policy
d. Use RSA to monitor the sensing accuracy of the PBR

5.4.2 DP102 Power Control

5.4.2.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to control transmitter power levels of the PBR.

5.4.2.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.2.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network.
b. Connect PBR master node to coupling network using an attenuator.
c. Connect all desired PBR slave nodes to coupling network using attenuators.
d. Establish DSA network and ensure communication between all nodes

5.4.2.4 Procedures

The test procedure shall be as follows:

a. Create a Power Control policy (e.g. If operating in 300MHz-350MHz band, set DSA transmitter power at level X; if operating in 350MHz-400MHz band, set DSA transmitter power at level Y.)
b. Load Power Control policy onto all PBR nodes
c. Monitor the transmitter power level using the RSA
d. Introduce appropriate AWG signal to force DSA network to change operating frequencies
e. Note the new transmitter power level. The transmitter power level should be changed automatically on the fly according to the loaded policy
f. Repeat Steps d-f several times to observe how the DSA network operates in different bands and ensure the PBR adjusts the transmitter power level as specified by the policy

5.4.3 DP103 Selective Frequency map

5.4.3.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to specify frequency bands on which the radio may and may not transmit.

5.4.3.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply

b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.3.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
d. Establish DSA network and ensure communication between all nodes

5.4.3.4 Procedures

The test procedure shall be as follows:

a. Create a selective frequency map policy which explicitly specifies certain acceptable bands of frequencies for operation
b. Load selective frequency map policy onto all DSA nodes
c. Introduce appropriate AWG signal to force DSA network to jump through frequency range
d. Monitor RSA to make sure DSA network does not operate on a frequency that is not permitted by the selective frequency map policy

5.4.4 DP104 Geospatial Operation

5.4.4.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to control the operation of the radio based on GPS location.

5.4.4.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)
e. GPS simulator

5.4.4.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect GPS simulator to one of the PBR slave nodes
b. Connect RSA and AWG to coupling network
c. Connect PBR master node to coupling network using an attenuator
d. Connect all desired PBR slave nodes to coupling network using attenuators
e. Establish DSA network and ensure communication between all nodes

5.4.4.4 Procedures

The test procedure shall be as follows:

a. Create a GPS-based policy (e.g., If geographic location is X, restrict allowed operating frequency to range Y)
b. Load GPS-based policy on all PBR nodes
c. Set GPS simulator to position slave node outside of location X
d. Monitor RSA to observe operating frequency of PBR node. The frequency should be within the frequency range as specified by the policy
e. While simulated GPS location remains outside of location X, introduce AWG frequency sweep signal to force DSA network to jump
f. Observe operating frequency of DSA network. The frequency should be within the frequency range as specified by the policy
g. Change GPS simulator to position slave node at location X
h. Observe operating frequency of DSA network. The frequency should be within the frequency range as specified by the policy
i. While simulated GPS location remains at location X, introduce AWG frequency sweep signal to force DSA network to jump
j. Observe operating frequency of DSA network. The frequency should be within the frequency range as specified by the policy

5.4.5 DP105 Time Based Performance

5.4.5.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to control the operation of the radio based on the time of day.

5.4.5.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.5.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
e. Establish DSA network and ensure communication between all nodes

5.4.5.4 Procedures

The test procedure shall be as follows:

a. Create a time-based policy (e.g., If time is within a range X, restrict allowed operating frequency to within range Y)
b. Load time-based policy on all PBR nodes
c. Set system time to be outside time range X
d. Introduce AWG frequency sweep signal to force DSA network to jump
e. Observe operating frequency of DSA network. The frequency should be within the frequency range as specified by the policy
f. Change system time to be within time range X
g. Introduce AWG frequency sweep signal to force DSA network to jump
h. Observe operating frequency of DSA network. The frequency should be within the frequency range as specified by the policy

5.4.6 DP106 Dense/Noisy Environment Performance

5.4.6.1 Purpose

This test procedure is used to characterize the effectiveness of a policy to maintain communication while operating in a dense or noisy RF environment.

5.4.6.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.6.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
d. Establish DSA network and ensure communication between all nodes

5.4.6.4 Procedures

The test procedure shall be as follows:

a. Generate wideband noise signal as described in Section 7.2.3
b. Load anti-jamming policy on all PBR nodes
c. With the noise signal off, ensure connectivity of DSA network
d. Turn the noise signal on
e. Observe operation of DSA network. The network should jump to emergency channel and start transmitting there, regardless of the jamming in that frequency band

5.4.7 DP107 Threshold Sensing Accuracy

5.4.7.1 Purpose

This test procedure is used to characterize the sensing accuracy of the detector as it applies to the threshold level which the radio is able to sense if there is another signal on the same frequency.

5.4.7.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.7.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network.
b. Connect PBR master node to coupling network using an attenuator.
c. Connect all desired PBR slave nodes to coupling network using attenuators.
d. Establish DSA network and ensure communication between all nodes

5.4.7.4 Procedures

The test procedure shall be as follows:

a. Set the detection threshold to be at the expected detection threshold level (DTL)
b. Generate an AWG signal to be 6dB below the expected normal detection threshold level at the PBR RF port. Take into account path loss in the lab's RF network setup
c. Turn on the AWG signal
d. Force the DSA network to operate on the lowest frequency of the allowed spectrum, frequency X
e. Observe the behavior of the DSA network. The network should not change frequencies since the AWG signal should be 6dB below DTL
f. Increase the AWG signal level in 1dB increments until the DSA network migrates due to sensing of the signal
g. Calculate percent error between expected detector threshold level and the actual threshold level observed
h. Repeat the test with the DSA network on frequency X, with the detection threshold level increased by 5dB to DTL+5
i. Repeat the test with the DSA network on frequency X, with the detection threshold level decreased by 5dB to DTL-5
j. Repeat the test with the DSA network operating on a frequency in the middle of the allowed spectrum, frequency Y, with threshold levels of DTL-5, DTL, and DTL+5
k. Repeat the test with the DSA network operating on the highest frequency of the allowed spectrum, frequency Z, with threshold levels of DTL-5, DTL, and DTL+5

5.4.8 DP108 Composite Policy Test

5.4.8.1 Purpose

This test procedure is used to characterize the performance of a DSA network with multiple policies loaded on the PBR.

5.4.8.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

5.4.8.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
d. Establish DSA network and ensure communication between all nodes

5.4.8.4 Procedures

The test procedure shall be as follows:

a. Create geospatial policy
b. Create Time-based policy
c. Create permissive/restrictive frequency policy
d. Create other policies, as desired. Policies in steps a-c are suggestions
e. Load desired policies on all PBR nodes
f. Vary the independent parameters of the above policies (e.g. GPS location, time of operation, etc.) and observe the operation of the DSA network to ensure proper selection of available frequencies, power levels, etc.

5.4.9 DP109 Cooperative Sensing Test

5.4.9.1 Purpose

This test procedure is used to characterize the performance of multiple DSA-enabled PBR nodes to cooperatively detect and communicate the presence of a hidden node. This is an important characteristic to address the hidden node problem in multi-node radio networks.

5.4.9.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)

d. Real-time Spectrum Analyzer (RSA)

5.4.9.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect RSA and AWG to coupling network
b. Connect PBR master node to coupling network using an attenuator
c. Connect all desired PBR slave nodes to coupling network using attenuators
d. Establish DSA network and ensure communication between all nodes

5.4.9.4 Procedures

The test procedure shall be as follows:

a. Create geospatial policy
b. Create Time-based policy
c. Create permissive/restrictive frequency policy
d. Create other policies, as desired. Policies in steps a-c are suggestions
e. Load desired policies on all PBR nodes
f. Vary the independent parameters of the above policies (e.g. GPS location, time of operation, etc.) and observe the operation of the DSA network to ensure proper selection of available frequencies, power levels, etc.

6. Quality of Service (QoS) Measurements

6.1 Scope

This section provides a list of general network QoS performance measurements to be collected to characterize the non-DSA specific metrics of the network in a lab environment. QoS measurements are network and application specific, and as such, cannot be exhaustively listed in the framework. The appropriate network QoS measurements must be determined by the user, based on the specific application, type of DSA PBR, network routing protocol, and other parameters. The following items represent a small sampling of available measurements which must be performed in conjunction with one of the Test Procedures as outlined in Section 5 above.

Bit error rate, packet error rate, latency, and jitter are important QoS measurements. However, this framework does not address the procedures for these measurements. The user is referred to existing standards and procedures to obtain these measurements.

6.2 Test Equipment

The test equipment shall be as follows:

a. Power Supply
b. Real-Time Spectrum Analyzer (RSA)
c. Traffic Generator

6.3 Setup

The test setup is described and shown in Section 4.3, and shall be as follows:

a. Connect PBR master node to the coupling network
b. Connect RSA to the coupling network
c. Connect the number of desired PBR slave nodes to the coupling network
d. Establish DSA network and ensure communication between all nodes
e. Connect Traffic Generator(s) to desired PBR node(s) and set traffic generation and communication between multiple nodes

6.4 Measurement Procedures

6.4.1 QS101 Payload Throughput

6.4.1.1 Purpose

This test procedure is used to characterize the payload throughput of the network.

6.4.1.2 Procedures

The measurement procedure shall be as follows:

a. Set the traffic generator for low data rate streams to establish baseline performance
b. Record throughput, packet type and size
c. Collect network performance statistics for TBD minutes

d. Increase data stream rates in TBD percent steps and collect statistics for each rate
e. Increase rates until statistics degrade to TBD

7. DSA Network Metrics

7.1 Scope

This section provides a list of DSA network metrics to be collected to characterize the performance of the DSA network in a lab environment. Any of these metrics must be measured in conjunction with one of the Test Procedures as outlined in Section 5.

This section is reserved for tests to be developed at a later time, such as DSA Network Overhead.

Electromagnetic Environment (EME) Lab Setup

7.2 Scope

This section provides a list of electromagnetic environments created in a lab in which a radio must be tested to characterize its real-world performance. All power levels mentioned are relative to the DSA radio threshold level. For characterization purposes, the power level is adjusted so it is just below the sensing threshold of the DSA signal, thus providing worst case performance in all EME setups.

7.3 EME Setup Procedure

7.3.1 EM101 Adjacent Channel Narrowband Signal

7.3.1.1 Purpose

This EME is used to characterize the performance of a radio in the presence of an adjacent channel narrowband signal. The definition of narrowband depends on the frequency band of interest. For example, in the UHF/VHF range, narrowband signal is defined as a signal with bandwidth less than or equal to 25 kHz wide. This signal is adjacent to the channel on which the DSA radios are operating on, with the channels being one DSA channel bandwidth apart measured center to center. The channel is defined by the occupied bandwidth of the PBR. By changing the PBR receiver sensitivity, the narrowband signal may impact the DSA network differently.

7.3.1.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. Policy Based Radio (PBR)
c. Arbitrary Waveform Generator (AWG)
d. Real-time Spectrum Analyzer (RSA)

7.3.1.3 Procedures

The setup procedure shall be as follows:

a. Form DSA network using the PBRs.
b. Observe the acquired operating frequency of the DSA network using a RSA.
c. Using the AWG, generate a narrowband signal with center frequency at the center of the adjacent channel. The power level of the narrowband signal must be 5dB above the sensing threshold of the DSA PBR network, to account for receiver sensitivity and sensing accuracy.
d. Feed AWG narrowband signal into the DSA network.
e. While observing the DSA network and the narrowband signal on the RSA, gradually decrease the power of the narrowband signal until it no longer forces the DSA network to jump to a different frequency. Note the power level of the narrowband signal. The

power level of the narrowband signal should be below the sensing threshold of the DSA PBR network.

f. Since the DSA network was forced to move to a different frequency several times, note the new frequency
g. Insert the generated adjacent channel narrowband signal into the DSA network through the coupling network.

7.3.2 EM102 Adjacent Channel Wideband Signal

7.3.2.1 Purpose

This EME is used to characterize the performance of the radio in the presence of an adjacent channel wideband signal. For this setup, wideband signal is initially defined as a signal with similar power and spectral density as the DSA radio signal. For characterization purposes, the power level is adjusted so it is just below the sensing threshold of the DSA signal, thus providing worst case performance.

7.3.2.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. Arbitrary Waveform Generator (AWG)
c. Real-time Spectrum Analyzer (RSA)

7.3.2.3 Procedures

The measurement procedure shall be as follows:

a. Form DSA network using the PBRs
b. Observe the acquired operating frequency of the DSA network using a RSA
c. Using the AWG, generate a wideband signal with center frequency at the center of the adjacent channel of the DSA network. The power level of the wideband signal must be same as the power level of the DSA signal.
d. Feed AWG wideband signal into the DSA network
e. If the DSA network was not forced to switch channels due to presence of the adjacent channel wideband signal, the wideband signal has been successfully created and the rest of the steps can be skipped.
f. While observing the DSA network and the wideband signal on the RSA, decrease the power of the wideband signal until it no longer forces the DSA network to jump to a different frequency. Note the power level of the wideband signal. The power level of the wideband signal should be below the sensing threshold of the DSA PBR network.
g. Since the DSA network was forced to move to a different frequency several times, note the new frequency
h. Input the generated wideband signal into the DSA network through the coupling network

7.3.3 EM103 Wideband Noise Signal

7.3.3.1 Purpose

This EME is used to characterize the performance of the radio in the presence of a wideband noise signal. A wideband noise signal is defined as a signal with bandwidth greater than twenty times the occupied bandwidth of the DSA signal.

7.3.3.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. Arbitrary Waveform Generator (AWG)
c. Real-time Spectrum Analyzer (RSA)

7.3.3.3 Procedures

The measurement procedure shall be as follows:

a. Form DSA network using the PBRs
b. Observe the acquired operating frequency of the DSA network using a RSA
c. Using the AWG, generate a wideband noise signal within the operating frequency range of the PBR. The power level of the wideband noise signal must be same as the power level of the DSA signal.
d. Feed AWG wideband noise signal into the DSA network
e. While observing the DSA network and the wideband noise signal on the RSA, decrease the power of the wideband noise signal until it no longer forces the DSA network to jump to a different frequency. Note the power level of the wideband noise signal. The power level of the wideband signal should be below the sensing threshold of the DSA PBR network.
f. Input the generated wideband noise signal into the DSA network through the coupling network

7.3.4 EM104 Frequency Swept Signal

7.3.4.1 Purpose

This EME is used to characterize the performance of the radio in the presence of a swept signal. For this setup, a signal is generated to sweep the operating band of frequencies of the DSA radio. This may affect the general networking measurements.

7.3.4.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. RF Signal Generator
c. Real-time Spectrum Analyzer (RSA)

7.3.4.3 Procedures

The measurement procedure shall be as follows:

a. Specify frequency range of the sweep to overlap the DSA network operating frequency band.
b. Specify number of points in the sweep (number of discrete frequencies to sweep).
c. Specify dwell time of each frequency.
d. Input the generated frequency sweep into the DSA network through the coupling network.

7.3.5 EM105 Frequency Hopping Signal

7.3.5.1 Purpose

This EME is used to characterize the performance of the radio in the presence of a frequency hopping signal. For this setup, a frequency hop signal is generated to transmit in the operating band of frequencies of the DSA radio. The frequency hop rate should be set to characterize the radio in different simulated EM environments. This can be performed with either the wideband or narrowband signals.

7.3.5.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. RF Signal Generator
c. Real-time Spectrum Analyzer (RSA)

7.3.5.3 Procedures

The measurement procedure shall be as follows:

a. Specify frequency range of the hop to overlap the DSA network operating frequency band
b. Specify number of points in the hop (number of discrete frequencies to hop).
c. Specify dwell time of each frequency
d. Input the generated frequency hop into the DSA network through the coupling network

7.3.6 EM106 High Power Signal

7.3.6.1 Purpose

This EME is used to characterize the performance of the radio in the presence of a high power signal. For this setup, a high power signal is defined as a signal whose power is TBD higher relative to the DSA radio signal.

7.3.6.2 Test Equipment

The required equipment shall be as follows:

a. Power Supply
b. Arbitrary Waveform Generator (AWG)

c. Real-time Spectrum Analyzer (RSA)

7.3.6.3 Procedures

The measurement procedure shall be as follows:

a. Generate an arbitrary high power signal waveform using the AWG.
b. Check the high power signal generated using the RSA.
c. Input the generated high power signal into the DSA network through the coupling network.